Design Science
A Prelude

The Experimental Economics Week
in Honor of
Dr. Vernon L. Smith
Kyoto Sangyo University

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Tatsuyoshi Saijo
ISER, Osaka University

Goal: Build up a Scientific Framework for Designing Institutions

Example: Public Good Provision

1. **Choice of Equilibrium Concepts**
   Is Incentive Compatibility enough?
2. **Theoretical Framework**
   Is the current framework of mechanism design all right?
3. **Research Methodology**
   What should be the framework for "Design Science"?

1. Choice of Equilibrium Concepts Is Incentive Compatibility enough?

1. Applicability Problem
Is there any incentive compatible (or strategy-proof) mechanism used in a real economy? Are we the worst sales people? Or, don't we have enough confidence to sell them?

2. Negative Experimental Evidence
Very few subjects reveal their true valuations
- Second price auction experiments: Kagel, Harstad, and Levin (1987), Kagel and Levin (1993) , Harstad (2000)
- Pivotal mechanism experiments: Attiyeh, Franciosi, and Isaac (2000) and Kawagoe and Mori (2001)

What's wrong?

One explanation:
Confusion due to the complexity of the mechanism and the non-transparency of the dominant strategy

Saijo, Sjöström and Yamato (2004): go beyond this explanation.

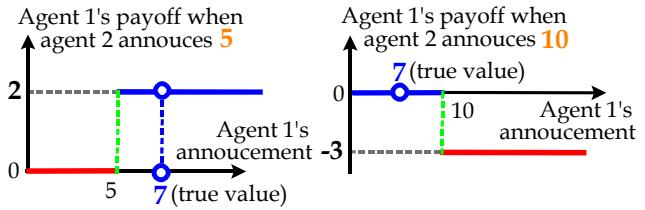
How will behavior deviate from the dominant strategy equilibrium?

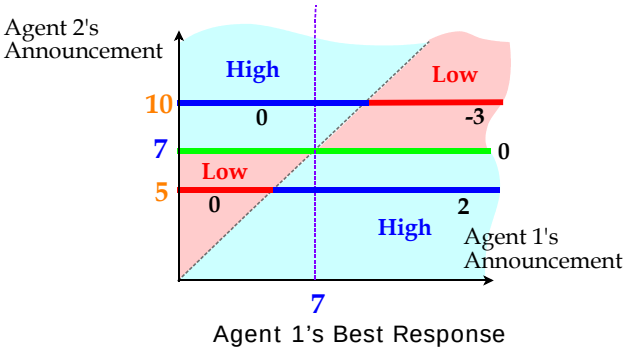
A look at equilibrium structures to identify systematic (rather than random) deviations from the dominant strategy equilibrium

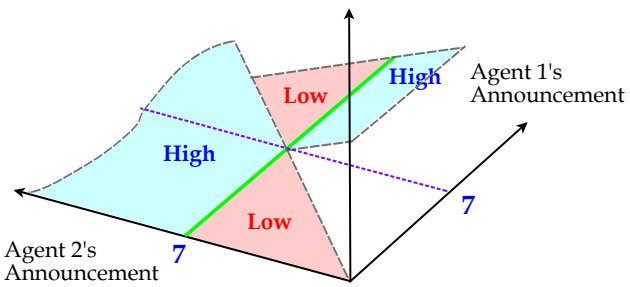
Multiple "Bad" Nash equilibria Exist!

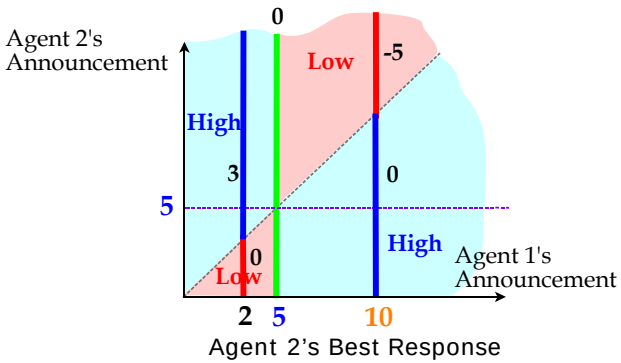
Example 1: Second Price Auction (Vickrey, 1961)
Agent 1 (true value=**7**) and Agent 2 (true value=**5**)
The highest bidder pays the second highest bid.

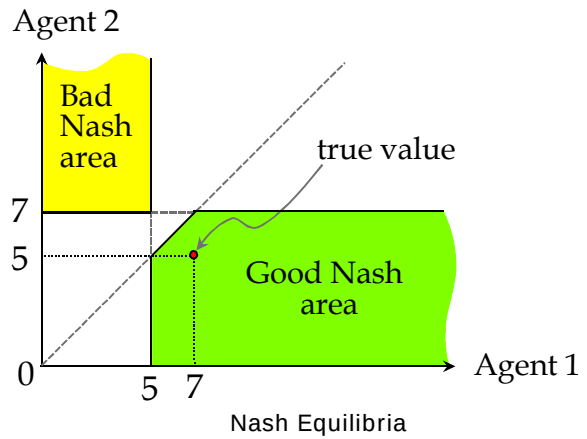
Theory says: both agents should announce their true value since telling the true value is a dominant strategy.



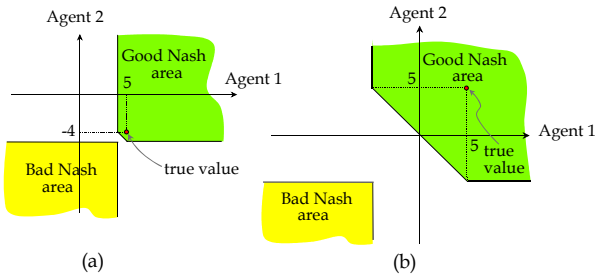








Example 2: Pivotal Mechanism (Clarke, 1971)



1. About a half region of strategy space is Nash equilibria.
2. One-fourth is **bad** Nash equilibria.

A Solution:

• Simultaneously implement a social choice function (SCF) in dominant strategies *and* Nash equilibria to exclude "bad" Nash equilibria equilibria

= **Secure Implementation**

Why not just Nash implementation to exclude Bad Nash?

• Mechanisms designed for Nash implementation may not work well in experiments.

• The strategic uncertainty: In the absence of a dominant strategy, a player's best response depends on the other players' choices, which may be hard to predict.

⇒ the failure to coordinate on a Nash equilibrium.

• Neither dominant strategy implementation nor Nash implementation provides a robust foundation for practical implementation.

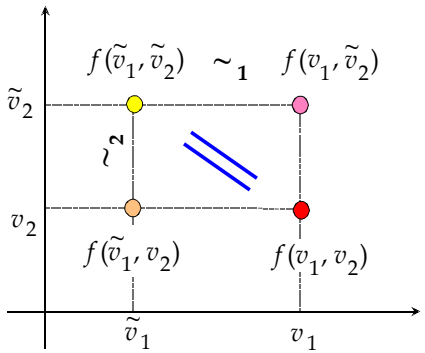
• We consider secure implementation in order to
(i) get the advantages of dominant strategies (strategic uncertainty is not important);
(ii) avoid the possibility that the players may play "bad" Nash equilibria.
(all Nash equilibria should yield a socially optimal outcome)

Note: secure implementation = multiple (more than double) implementation in dominant strategy equilibria, Nash equilibria, and all refinements of Nash equilibria

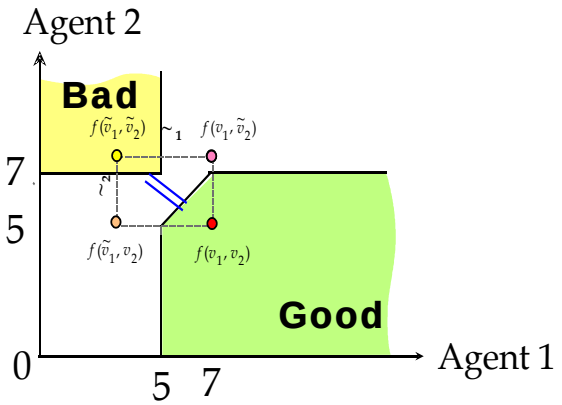
Secure Implementation in Public Good Economies: Saijo, Sjöström and Yamato (2004)

Secure implementability
⇒ dominant strategy implementability
⇒ incentive compatibility
(**Revelation Principle,** Gibbard, 1973)

Another condition is necessary for secure implementation.

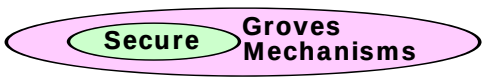


Rectangular Property



Theorem 1 (Saijo-Sjöström-Yamato (2004)). *An SCF is securely implementable if and only if it satisfies incentive compatibility and the rectangular property.*

Theorem 2 (Saijo-Sjöström-Yamato (2004)).
(i) *For any mechanism implementing an efficient SCF in dominant strategy equilibria, the set of Nash equilibrium outcomes is strictly larger than that of dominant strategy equilibrium outcomes if the number of public project choices is finite.*
(ii) *Assuming that preferences are single-peaked and the choice of public project is continuous, incentive compatible and efficient SCF's are securely implementable by Groves-Clarke mechanisms.*



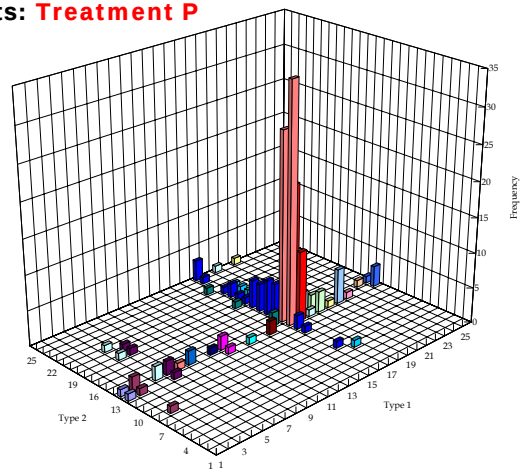
The Experiment: Cason, Saijo, Yamato and Sjöström (2004)
(i) The pivotal mechanism (Treatment P) and
(ii) a Groves-Clarke mechanism with single-peaked preferences (Treatment S).

Two sessions with 20 subjects for each treatment

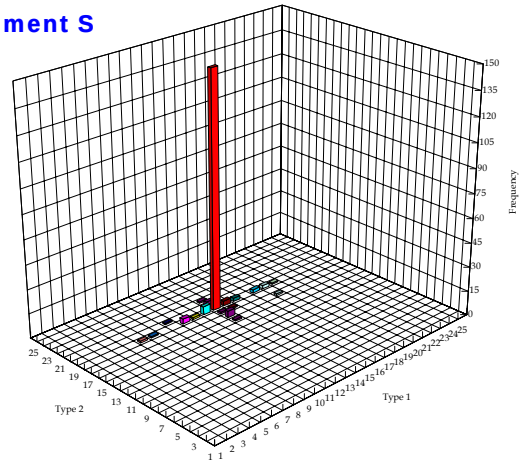
Use payoff tables: Context-free experiments!

Procedures
(i) A pair plays the game and the pairings were determined in advance by experimenters so as not to pair the same two subjects more than once ("strangers").
(ii) No subject knew the payoff table of the other type.
(iii) No explanation regarding the rules of the mechanisms or how the payoff tables were constructed.
(iv) Eight periods in Japan and ten periods in the U.S.

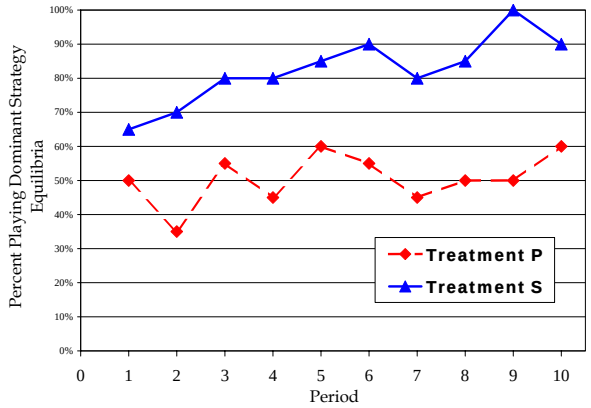
Results: Treatment P



Treatment S



Rates that Pairs Play Dominant Strategy Equilibria



The Problems

1. **The class of secure social choice functions is very thin => impossibility results**

2. **Johansen Critiques:**
   (a) The framework of preference revelation is far from the political process of public goods provision.
   (b) Almost no incident when public goods were provided by preference revelation.

2. Theoretical Framework
Is the current framework of mechanism design all right?

The Groves and Ledyard mechanism (1977)
The Walker Mechanism (1981)
The Hurwicz Mechanism (1979) and others

constructed mechanisms to achieve a socially desirable allocation.

The Free-Rider Problem is solved!?

Fundamental difficulties in mechanism design in economies with public goods

- Previous mechanism design including Groves-Ledyard, Walker, Hurwicz and almost all mechanisms assume that everyone MUST participate in a mechanism.

⇓

- Ignore NON-EXCLUDABILITY of a public good: non-participants can enjoy the public good provided by participants

- **Examples:**

<International Treaties>

- The Kyoto Protocol on climate change (1997) to reduce green house gas emissions: the U.S. signed the protocol, but decided not to ratify it

<Public Fee to public goods>

- NHK's Public Broadcasting Fee in Japan
  no penalty without paying the fee

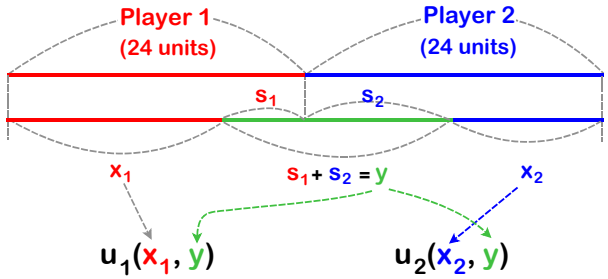
What would happen if we consider voluntary participation?

- **Saijo and Yamato** (*JET*, 1999):
Participation is a choice variable for agents

An impossibility theorem:
It is impossible to design a mechanism in which everyone has an incentive to participate.

- **Experiments**
  Cason, Saijo and Yamato (*Exp. Econ.*, 2002)
  Cason, Saijo, Yamato and Yokotani (*GEB*, 2004)

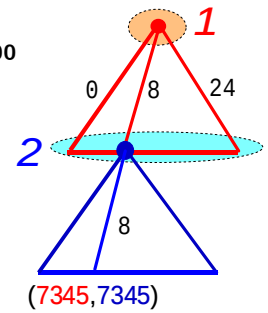
The Voluntary Contribution Mechanism: A two agent game where each agent decides to contribute her money for constructing a public good.



• **Represent the VCM by a Game Tree**

$$u_i(x_i, y) = \frac{(x_i^{0.47} y^{0.53})^{4.45}}{50} + 500$$

Nash Equilibrium:
$(s_1, s_2) = (8,8)$

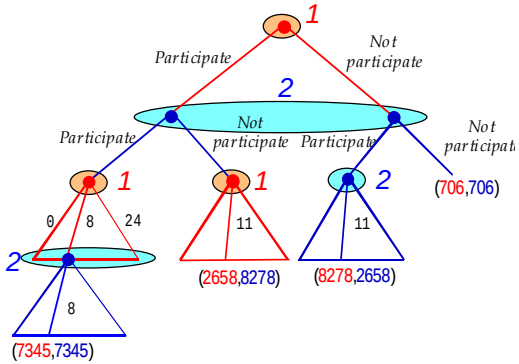


s_1

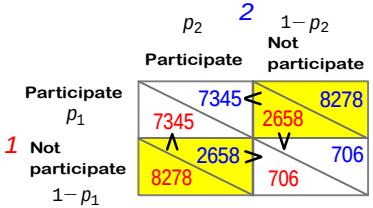
s_2 / Your Payoff	0	1	2	3	4	5	6	7	8	9	10	11	12
0	706	871	1072	1297	1536	1775	2003	2210	2386	2523	2615	2658	2648
1	905	1127	1379	1647	1919	2183	2427	2641	2816	2944	3019	3039	3001
2	1186	1465	1764	2072	2374	2658	2913	3129	3297	3411	3465	3456	3385
3	1554	1888	2232	2575	2902	3202	3463	3675	3831	3925	3952	3911	3801
4	2017	2401	2787	3160	3508	3817	4078	4281	4420	4488	4483	4403	4250
5	2578	3010	3432	3831	4193	4507	4762	4950	5064	5101	5057	4934	4733
6	3244	3718	4171	4590	4960	5272	5515	5681	5766	5765	5677	5504	5249
7	4018	4529	5008	5440	5812	6115	6339	6478	6526	6481	6343	6114	5800
8	4904	5447	5944	6383	6751	7038	7237	7340	7345	7250	7056	6765	6385
9	5907	6475	6984	7422	7779	8043	8209	8271	8225	8073	7816	7458	7007
10	7031	7616	8130	8561	8897	9132	9257	9270	9168	8951	8624	8193	7664
11	8278	8873	9384	9800	10109	10306	10384	10339	10173	9886	9482	8970	8359
12	9653	10250	10750	11142	11416	11567	11589	11480	11242	10877	10390	9791	9090

Best Responses

• **Adding a Participation Stage**



• **Looking at the Participation Decision** ⇒ A Hawk-Dove Game ⇐ Not a prisoner's dilemma game



The set of Nash equilibria
$\{(p_1, p_2):(1,0),(0,1),(0.68,0.68)\}$
Evolutionarily stable strategy $p_i = 0.68$

• **Evolutionarily Stable Strategy Equilibrium (or John Maynard Smith Equilibrium)**

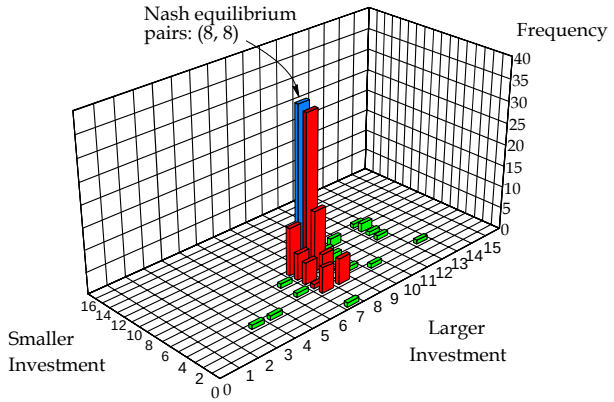
• **Experimental Design**

Tsukuba & Tokyo Metro in Japan | USC & Purdue in the US

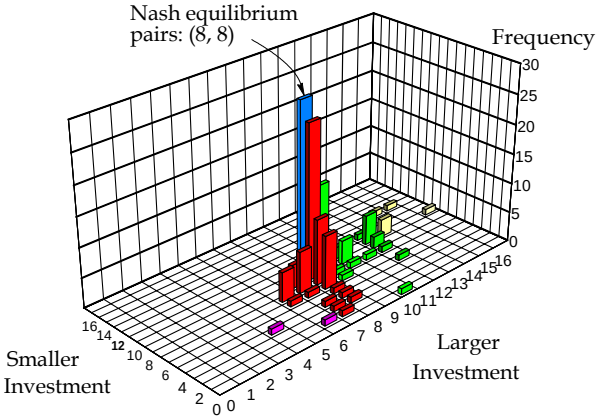
Treatment A: Every subject must participate in investment.
- 20 subjects
- 2 subjects make a pair (10 pairs)
- No communication
- Each subject does not know who is your opponent
- 15 periods
- No subject faces the same subject twice or more
- Every subject knows that every subject has the same payoff table
- A pair knows the investment decision each other, but this info is not in public.

Treatment B: each subject can choose whether she participates in investment or not

Result: Treatment A at Tsukuba



Result: Treatment A at USC



• **Spiteful Behavior**

s_1

s_2 / Your Payoff	0	1	2	3	4	5	6	7	8	9	10	11	12
0	706	871	1072	1297	1536	1775	2003	2210	2386	2523	2615	2658	2648
1	905	1127	1379	1647	1919	2183	2427	2641	2816	2944	3019	3039	3001
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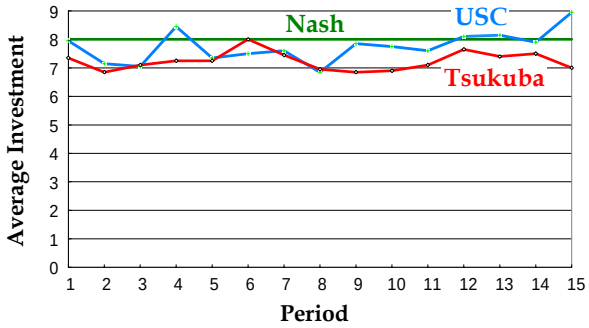
11	8278	8873	9384	9800	10109	10306	10384	10339	10173	9886	9482	8970	8359
12	9653	10250	10750	11142	11416	11567	11589	11480	11242	10877	10390	9791	9090

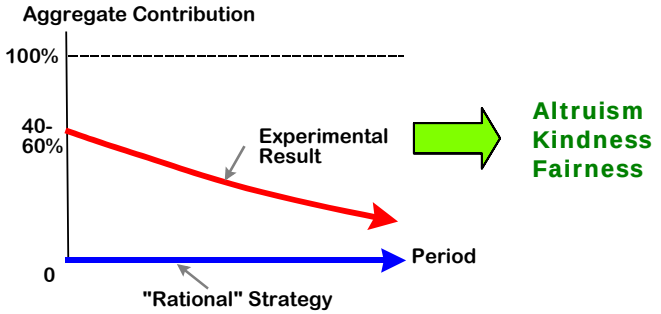
Your Payoff	7	8
7	6478<	6526
8	7340<	7345

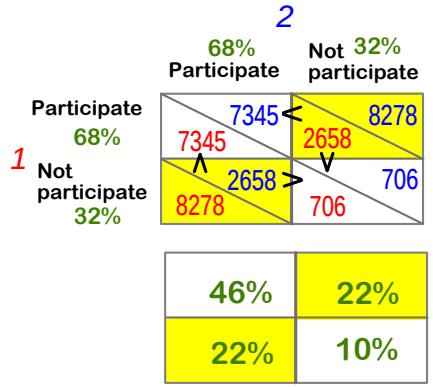
Assume that the other player chooses 8.
Choose 7 rather than 8
Reduce own payoff from 7345 to 7340 (5 units)
The other player reduces from 7345 to 6526

Treatment A: No participation decision



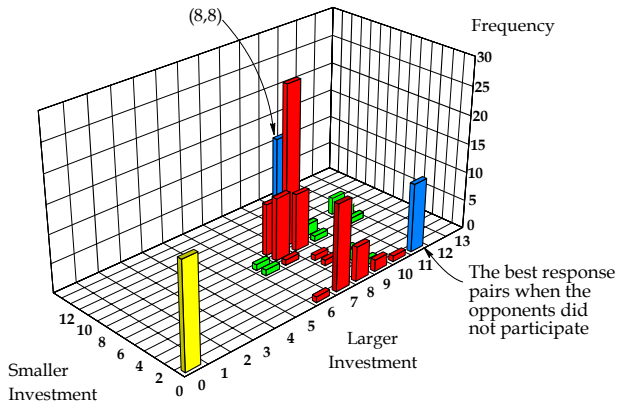
Stylized Facts in Linear Indifference Curve Public Good Experiments



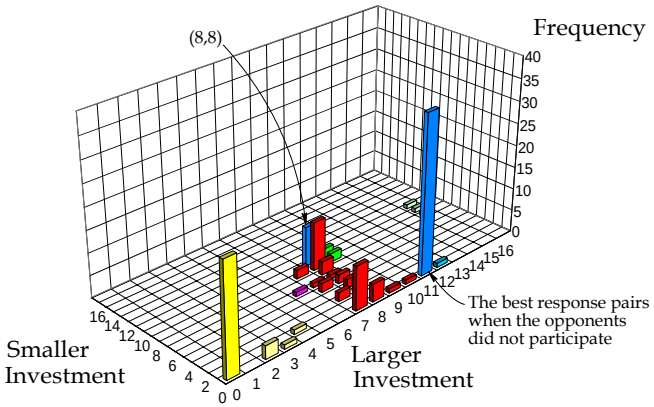


46%	22%
22%	10%

Result: Treatment B at Tsukuba



Result: Treatment B at USC



• Spiteful Behavior

s_1

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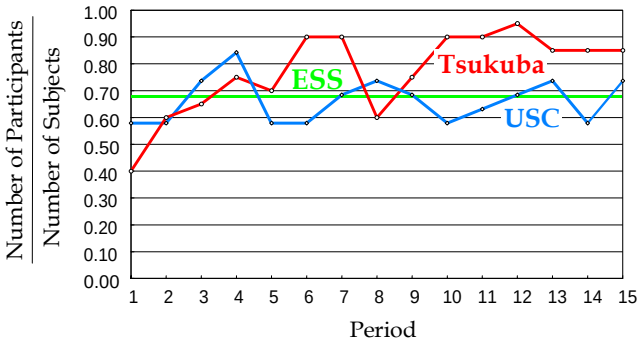
s_2

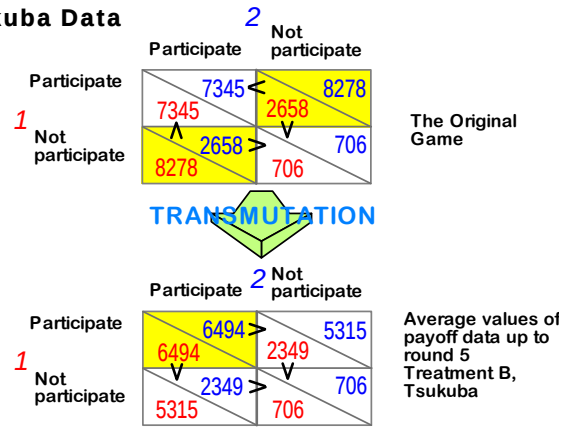
The best response when the other player does not participate = 11.
Choose 7 rather than 11
Reduce own payoff from 2658 to 2210 (448 units)
The other player reduces from 8278 to 4018 7345 to 6526

See also **Saijo & Nakamura** (*J. Conflict R.*, 1995), **Ito, Saijo and Une** (*JEBO*, 1995), & **Brandts, Saijo & Schram** (*Public Choice*, 2004)

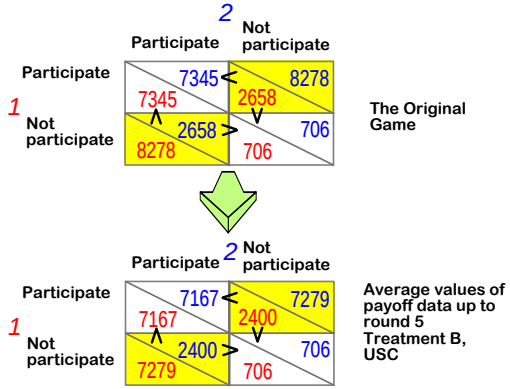
Participation decisions



Tsukuba Data



USC Data

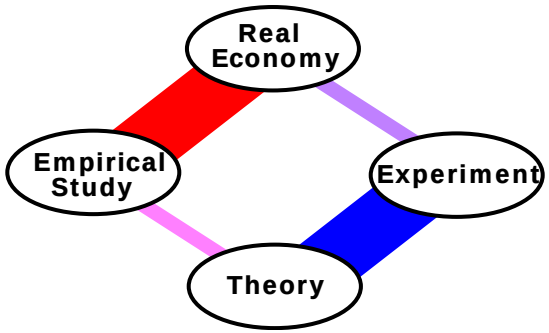


3. Research Methodology
What should be the framework for "Design Science"?

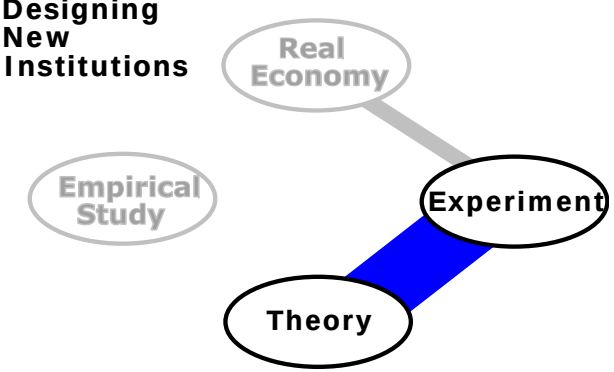
A describer's point of view:
Experimentalists are optimistic

A designer's point of view:
Experimentalists are pessimistic

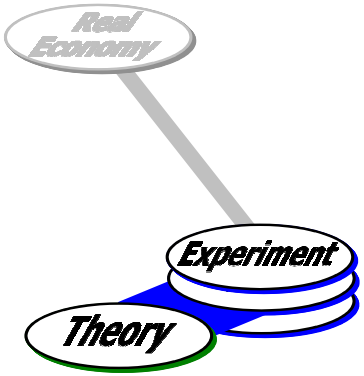
Example: Design mechanisms to attain the goal of the Kyoto Protocol in order to mitigate global warming such as carbon tax, emissions trading and so on.



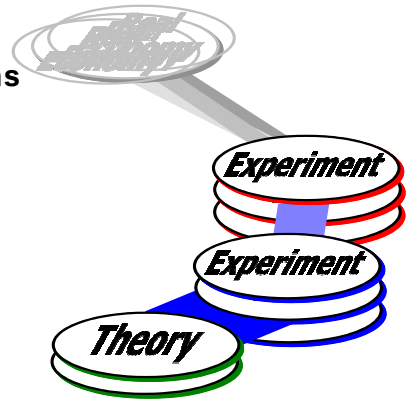
Designing New Institutions



Designing New Institutions



Designing New Institutions



New Questions

1. What elements should we include in theories and experiments?
2. How far should we conduct the experiments?
3. How much should we rely on theories?

References:
Saijo, T., T. Sjöström and T.Yamato, "Secure Implementation," mimeo., 2004.
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Tatsuyoshi Saijo
Institute of Social and Economic Research
Osaka University
6-1 Mihogaoka
Ibaraki, Osaka 567-0047
Japan
saijo@iser.osaka-u.ac.jp